

## DEVICE FOR MEASURING ANGULAR POSITIONS

The present invention relates to a device for measuring angular positions using radar pulses having mutually overlapping beam characteristics of at least two antenna elements.

## Background Information

- 5 Radar sensors for recording the nearby motor vehicle environment (SRR, short range radar sensors) are provided for functions such as backup aid, parking assistance, parking gap measurement, blind spot monitoring, slow bumper to bumper driving or precrash detection.

Besides the information on the distance of relevant objects (other vehicles, traffic lane limitations or parking gap limitations, pedestrians, ...) information on their angular position  
10 relative to the vehicle is also important for judging the relevance of detected objects for whatever the vehicle is doing. The state of technological development is to calculate the angular direction of objects via so-called trilateration. In this method, the distance data of several neighboring sensors are used in order also to determine the angular deviation of targets, using simple trigonometric conversions. The disadvantage of this method is that more  
15 and more sensors are required at a certain distance apart, even to ascertain the position of only one target. Then too, these sensors in each case have to detect the same target, so as not to obtain faulty estimations.

- From WO 00/49423, a monopulse phase array antenna system is known, which has transmitting and receiving modules which are controlled by a beam swivel control device.  
20 From the received signals from the various antenna elements, composite signals and angular differential signals are derived. Each of the transmitting and receiving modules is furnished with two  $180^\circ$  phase shifters, in order to determine the angular differential signals. For the independent tracking in the azimuth and elevation direction it is known that one may evaluate a composite signal and two differential signals.
- 25 From M. Skolnik, Introduction to Radar Systems, second edition, McGraw Hill Book Company, 1980, pages 160 and 161 it is known that one may obtain the angular information of a target object from two mutually overlapping antenna beam characteristics.

## Summary of the Invention

- 30 Using the device according to the features of Claim 1, it is possible to obtain angular data from an overall radar position finding field, at a very limited additional hardware expenditure.

Advantageous embodiments are shown in the dependent claims.

Using the measures of the present invention, it is not necessary to provide in each receiving path a separate down converter and separate NF processing. Using the present invention, it is possible to implement the measurement of angular positions even using a single sensor.

- 5 Compared to an implementation that is used only for distance measurement, the position finding field may remain virtually unchanged. The additional hardware expenditure is limited to a simple phase shifter having a simple signal evaluation.

- 10 Because of the angular measurement according to the present invention, it is possible to minimize the number of sensors required for certain functions. A backup aid may be equipped with only one angle measuring SRR sensor, whereas conventional systems require three sensors. At slow bumper to bumper driving, only one or two sensors would be necessary using the implementation according to the present invention instead of three or four sensors, as in conventional systems. One sensor is sufficient for blind spot monitoring, instead of two that are usual otherwise.

#### 15 Brief Description of the Drawings

In the following, exemplary embodiments of the present invention are explained with reference to the drawings. The figures show:

- Figure 1 an implementation according to the present invention having a dual beam antenna and a switchable phase shifter,
- 20 Figure 2 the amplitude curve of a dual beam sensor,
- Figure 3 the phase curve of a dual beam sensor,
- Figure 4 a dual beam antenna with wiring,
- Figure 5a and b dual beam antennas having an  $180^0$  hybrid (rat race),
- 25 Figure 6 an antenna system having 2x2 columns for time-division multiplex operation,
- Figure 7 the antenna system as in Figure 6 having an 180-hybrid.

#### Description of the Exemplary Embodiments

In the present invention, the known radar monopulse technique is used for angular measurement, in which information about the angular deviation is able to be derived via the

comparison of received signals in different, mutually overlapping beam lobes and knowledge of the radiation characteristics themselves (comparable to so-called “best fit matching” of the received signals). This evaluation method is very similar to the one used also in long range radar (LRR, ACC). In LRR radar, three or four reception lobes are formed, and their mutual  
 5 overlapping is drawn upon for the angle estimation using the comparison of the received signals.

In the device according to the present invention for measuring angular positions, two different receiving characteristics are generated having as widely overlapping areas as possible. To do this, according to Figure 1, at least two antenna elements 1 and 2 are used,  
 10 each having adjustable oscillation phases. The different phase conditions are produced by an interposed HF component, and in the example according to Figure 1 this is a switchable phase shifter 3, which is interposed in one of the two antenna paths shown here. By switching phase shifter 3, the oscillation phase of antenna element 2 is set differently from that of antenna element 1, whereby the directivity characteristics of the overall system may be  
 15 considerably influenced. The signals of both antenna elements 1 and 2 in the reception path are subsequently brought together additively (summation node 8) and supplied to a mixer unit 4 (mixture with a mixing oscillator LO) and to further processing (filtering 5, analog/digital conversion (ADC) 6, evaluation device 7).

Figure 2 shows, for example, for a simple model of a patch antenna (for other antenna  
 20 element characteristics, slightly different beam characteristics come about) the amplitude characteristics of the overall system for both switching conditions of phase shifter 3. The characteristics of beam 1 come about because of the in-phase control of both antenna elements, i.e. phase shifter 3 is in switching state  $0^0$  (beam 1 = composite beam or in-phase beam). Thereby, in the main beam direction, a maximum forms in the common beam  
 25 characteristics, by the constructive superimposition of in-phase components. Beam 2 is obtained by a phase shift of  $180^0$  in the path of antenna element 2 (or 1), and in the main beam direction, the components of antenna elements 1 and 2 thereby exactly cancel each other (destructive superimposition), so that the direction characteristics in this direction form a zero point (beam 2 = difference beam or push-pull beam). The result on the side is a  
 30 symmetrical forming of two main lobes that are identical in the ideal case. Figure 3 shows the appertaining phase curves of both receiving characteristics. While the phase of beam 1 is (mirror) symmetrical to the main beam direction for reasons of symmetry, a centrosymmetric curve comes about for beam 2. This is decisive for the intended angle determination of a target, because a decision is only possible by the non-symmetry of at least one of the two

phase curves, as to whether there is a target to the left or to the right with respect to the orientation of the sensor.

For the angle determination itself, back and forth switching takes place between the two phase states, and thereby between the two directivity characteristics (operation in  
 5 time-division multiplexing). This switching takes place so rapidly that the influence of amplitude changes and phase changes of the incident wave front of a target as a result of relative motions of the target (target fluctuations) or of the transmitter with respect to the receiving antenna is negligible or is still able to be compensated for by appropriate correcting measures. Only then is it possible to have sufficiently accurate information about which  
 10 portion of a relative amplitude change and phase change of both directivity characteristics in the receiving channel is clearly to be apportioned to the angular deviation of the target, and not perhaps to other effects named above. On the other hand, the switching period should also not be too small, since otherwise the very cost-effective approach of the direct mixing of the HF carrier signal into the NF baseband (the so-called homodyne formulation, baseband  
 15 frequency portions in the kHz range) would have to be appropriately modified. To obtain the optimal switching frequency between the antenna characteristics, the relative motions of targets or sensor carriers (one's own vehicle) have to be negligible or able to be compensated for in the evaluation (target angle estimation), (determining for the upper limit of the switching period) but on the other hand a homodyne formulation (determining for the lower  
 20 limit of the switching period). At HF carrier frequencies in the GHz range, switching periods in the range of a few  $\mu\text{s}$ , e.g. 5 to 50  $\mu\text{s}$  are advantageous.

If these time-related effects (target fluctuations, relative motions) are minimal or if they are appropriately compensated for or taken into consideration by correcting variables, the angle of the target is given by a comparison of the relative amplitude change and phase change in  
 25 the receiving path in both switching states having the two complex-valued directivity characteristics of the antenna system (composite and differential beam). Over the entire angle range, in order that no ambiguities shall appear with respect to the comparison of the received signals to the directivity characteristics, additional lobes (secondary lobes) in beams 1 and 2 should be avoided. This is possible if, for example, the distance  $d$  of the two antenna  
 30 elements (see Figure 1) is within the range of the half wavelength, for instance, at 24 GHz approximately 6.5 mm.

Figure 4 shows a specific embodiment in which the two antenna elements 1 and 2 are formed here, for example, in each case by four radiating elements. These have the task, at vertical  
 35 positioning to the roadway surface after being assembled in the vehicle, to focus the energy in the vertical direction (elevations focusing) in order thereby to attain an appropriate range, but

also in order not to receive reflections from the roadway that are too strong. In the horizontal plane (azimuth) only minor focusing comes about per column, so that the directivity diagrams in the azimuth are very broad, similar to the ones in Figure 2, in order to obtain a horizontal detecting range that is as big as possible, and especially here too, to have an overlapping of the two directivity diagrams that is as broad as possible.

The sketched feedthroughs 9 in Figure 4 have the task of concentrating the HF components which require component assembly, such as the  $180^\circ$  phase shifter 3, in the plane or rather on the layer where still further assemblies are required (mixer 4, etc), so that a double-sided assembly may be avoided. In this embodiment, filter 5 is a low-pass filter TP, provided that the radar sensor principle is based on a homodyne set-up, that means that the received signal is both transmitted using an oscillator (not shown here) and also mixed directly into the baseband (direct conversion). Other specific embodiments are also possible, such as a heterodyne set-up having mixing in an intermediate frequency plane via additional oscillator, with the filter then designed as a bandpass.

Figure 5a shows still another possibility of how the angle determination according to the type described above may be made. As the phase-setting element, a so-called  $180^\circ$  hybrid 10 is used, which in the literature is called a rat race. This has the property of uniformly subdividing a signal incident at a gate to the gates lying opposite to it, and at a relative phase difference of  $180^\circ$ , while the fourth gate is isolated. Because of the reciprocity and linearity of this component, it is possible, in exactly the same way, to emit two signals to two input gates and to pick off, at the two gates lying opposite to this, the composite signal and the differential signal, that means, in this case, the composite beam and the differential beam. What is advantageous in this approach is that both beams are present at the same time, so that the negative influence of target fluctuations or relative motions does not appear here. The disadvantage is that both gates each require one mixer of their own, one filter and one AD converter (hardware expenditure).

Alternatively, the two gates of the rat race may also be supplied to a mixer in time-division multiplexing via a suitable transfer switch (Figure 5b).

Figures 6 and 7 further show embodiments having two columns each per antenna element. By an embodiment having more than one antenna column per antenna element, it is possible to obtain a concentration of the received energy in a horizontal plane. In this manner, a greater antenna gain, and thus a greater radar operating range is achievable, whereas the overlap area of composite beam and differential beam are hemmed in thereby. This may be advantageous for functions like, for instance, backup assistance. This embodiment may also be

advantageous for certain functions in which a certain suppression of signals (disturbing station) in the side region is rather desirable, e.g. from guardrails or other developments at the edge of the roadway. This is directly supported by the strong focusing of multi-column antenna elements.

- 5 Phase shifter 3 may advantageously be developed as PIN diode phase shifter.

A radar sensor according to the present invention may include, in a highly integrated design, the phase shifter or possibly the transfer switch, the signal junction (T junction, Wilkinson divider, or others), the mixer and possibly additional low-noise preamplifiers (LNAs) in an MMIC (monolithic microwave integrated circuit).

- 10 As phase shifter 3 one may also use an RF MEMS  $180^\circ$  phase shifter (RF radio frequency, MEMS = microelectromechanical system).

The antenna elements may be provided in various designs: radiating element, columns, several columns jointly per antenna element, so-called patch radiators, etc.

As transfer switch 11, PIN diode switches or MEMS switches may be used.